Assembly of Aligned Silver Nanowires using Roll-to-Roll System

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Silver nanowires (AgNW) have been extensively used in the last decade as a novel nanomaterial for applications in multifunctional electrical conductors. Having high aspect ratios and surface areas, they can be mechanically compliant while maintaining low resistivity. AgNW can be used for transparent and flexible optoelectronic devices such as touch screen and conformal display. Other applications include flexible electronic devices that can be readily mounted on the skin or fabric. However, existing work is generally based on random mixture of AgNW within a bulk polymer matrix, which has high optical absorption. By improving the optical properties, AgNW can further find applications in stretchable, transparent conductors, such as electronic contact lens.

Most existing nano-manufacturing approach using AgNW is focused on the establishing a percolation network within the bulk film to improve the electrical conductivity [1]. However, to obtain both optimal electrical and optical properties, aligning the AgNW in a particular direction in a monolayer is important. The available research work focuses on aligning silver nanowires using a magnetic field or using processes such as nano-combing where the nanowires are made to pass through a comb like structure with nano-slits and are difficult to scale [2]. For the feasible use of AgNW in the flexible electronics industry an easy manufacturing approach is required.

In this work, the nanowires are coated on a silicon substrate using a roll-to-roll (R2R) system, as depicted in Fig. 1 [3]. A solution of AgNW having an average length of 50 μm diluted in 0.5 M butanol was injected to float on the water surface and coated on a Si substrate using the R2R setup. However, the nanowires are misaligned and spread in a random order if the cartridge for Langmuir-Blodgett assembly has a uniform width as shown in Fig. 2(a). The alignment of the disoriented nanowires can be significantly improved by putting a slant angle in the roll-to-roll system, which decreases the width of the cartridge and constricts the flow. This confinement induces a lateral pressure so the AgNWs push against one another and self-align. By implementing a 70% restriction in the flow path in the R2R system, the AgNWs show significant improvement in alignment on the substrate, as shown in Fig. 2(b).

We will report the parametric study of nanowire alignment as a function of flow path reduction and lateral pressure. To validate the results, electrical properties of the misaligned and aligned nanowires can be studied. This will be achieved by using image analysis of top-view SEM. We will also characterize the electrical and optical properties of the aligned AgNW on a flexible polymer substrate, which is expected to improve significantly. We will also present more details regarding the pre-treatment process to control the length uniformity of the wires and the systematic optimization of the system operation parameters. This work will pave a path for future research applications in transparent, stretchable conductors.

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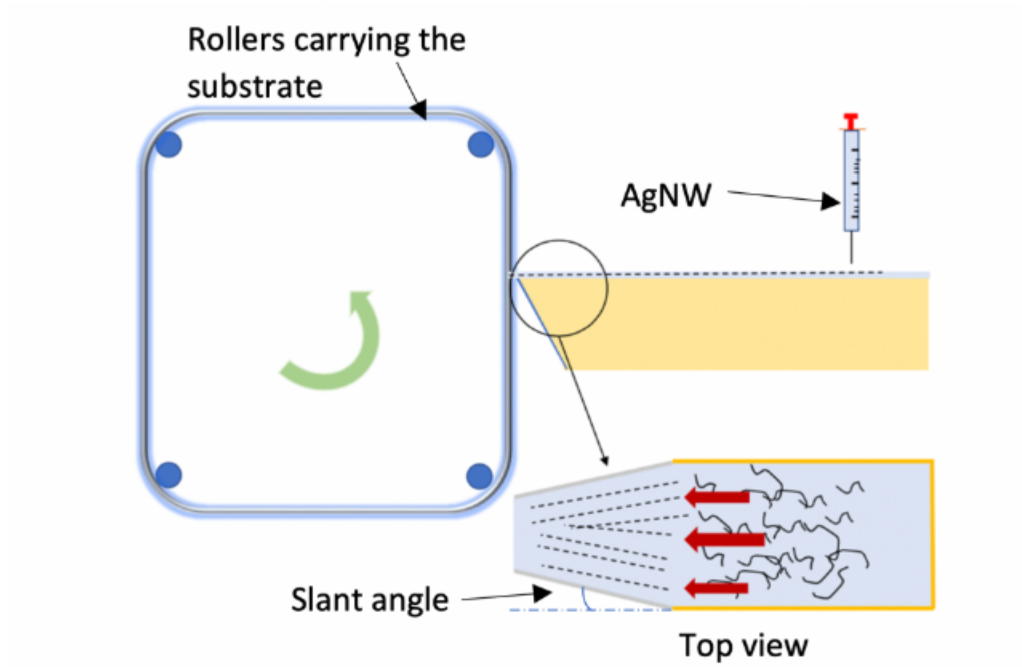

Fig. 1 Schematic diagram of the R2R experimental setup for AgNW alignment and assembly. The nanowires assemble on the liquid surface and are aligned by the liquid shear and lateral pressure.

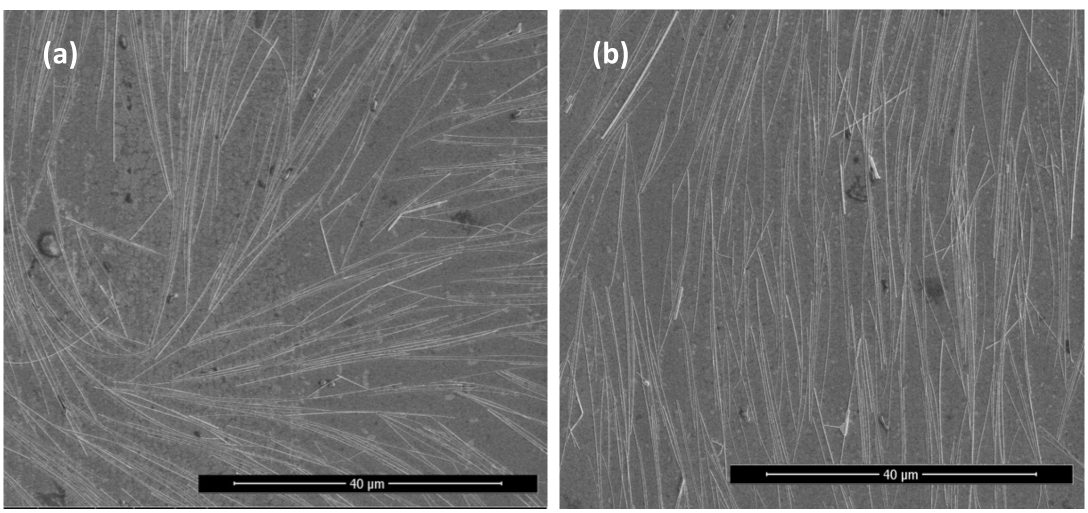

Fig.2 Silver nanowire assembled on Si substrate (a) misaligned; (b) after alignment.

Reference

[1] Feng Xu, Yong Zhu, *Advanced Materials*, **24**, 5117-5122 (2012).
[2] Jun Yao, et al. *Nature Nanotechnology,* **8**, 329–335 (2013).
[3] I-T. Chen et. al., *presented at EIPBN 2018*, San Juan, PR.